Dynamic Analysis of Loop Formation in Cables under Compression

Caroline Gatti and N. C. Perkins
Mechanical Engineering
University of Michigan
2250 GG Brown
Ann Arbor, MI 48109-2125
Tel : (734) 936-0403
Fax : (734) 647 3170
gattic@umich.edu
ncp@umich.edu

Keywords: Cable dynamics, Elastica, Hockling, Finite differencing, Euler parameters

Cable payout systems are widely used to deploy cables from a surface ship onto the ocean floor. Previous research on payout systems has ignored the effects of torsion on the cable due to the associated modeling and numerical complexities. However, when a cable is paid out and touches the seabed, the tension is drastically reduced and torsion becomes significant. In fact, under torsion, a low-tension cable can form a loop. This phenomenon is sometimes referred to as *hockling*. Loops must be avoided because they may ultimately kink the cable or otherwise degrade its performance. For example, a tight loop in a telecommunication cable may block signal transmission. This work extends prior models of cable loop formation by explicitly including dynamic effects.

A cable model is developed in which the cable is considered to be a one-dimensional elastic continuum that is able to support tension, bending, and torsion. In essence, the cable is treated as very slender (non-uniform) elastica that is allowed to undergo arbitrarily large rotations. Euler parameters are used in the development of the model. The resulting equations of motion constitute a nonlinear initial-boundary-value problem. The numerical strategy to integrate the equations of motion is based on a separate finite differencing in time and in space, and follows three steps. The first step is to discretize in time using backward differencing to obtain a nonlinear boundary-value problem in space. The nonlinear boundary-value problem is then linearized through a first-order Taylor series expansion of the field equations. Finally, this linearized boundary-value problem is transformed into a linear initial-value problem (in space), which is then solved without iteration using a numerical shooting method. The solution strategy is then advanced to the next time step where the original nonlinear initial-boundary-value problem is updated. Solution convergence is obtained upon refining both spatial and time steps.

The dynamics of loop formation is studied on a simple model that does not include payout, to gain a fundamental understanding of the loop formation process. Both a two-dimensional and a three-dimensional model are developed. The cable is positioned between two supports. The first support is fixed in space, and the second support moves towards the first support. Both fixed and simple (spherical joint) supports are studied.

Depending on the type of supports, we observe loop formation and in-plane and/or out-of plane dynamic instabilities.